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Rocket and Laboratory Studies in Astronomy

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Status Report for the Period
September 1, 1993 - August 31, 1994

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I. INTRODUCTION

This report covers the period from September 1, 1993 to August 31, 1994. During the reporting period we launched the Faint Object Telescope to measure the absolute flux of a hot white dwarf star in the spectral range below 1200 Å. This experiment was not successful due to a failure of an electronics unit in the onboard TV acquisition system. The source of the failure has been identified and corrected and is described in detail below. The payload was recovered in excellent condition and we are planning to refurbish it for flight during the November 1995 Australia campaign. We have continued our laboratory studies of the ultraviolet performance of charge-coupled-detector (CCD) arrays and plan to include a UV-sensitive CCD in a new payload that was assembled during the current period. The objective of the experiment is the ultraviolet imaging of Jupiter and we are scheduled to launch the payload, 36.115UG, in May-June 1995. We have also begun the design of a high resolution FUV spectrograph for a future flight of the FOT and have just recently received a high line density grating fabricated by Jobin-Yvon, S.A. (France) for evaluation. Work has continued on the analysis of data from previous rocket experiments.

II. ROCKET EXPERIMENTS

36.109 UG

On April 17, 1994, at 10:30 pm MDT, sounding rocket experiment 36.109UG was launched from White Sands Missile Range (WSMR). This experiment experienced two technical anomalies, one of which resulted in a failure to achieve the minimum success criteria of the mission. The scientific objective of 36.109 was to obtain an absolute calibrated spectrum in the wavelength region of 912 to 1300 Å of the hot type DA white dwarf star, G191-B2B. For purposes of wavelength calibration, the flight plan also called for acquiring ultraviolet spectrum of Capella, one of the two bright guide stars used for pointing maneuvers.

The experiment consists of a 40 cm Dall-Kirkham telescope focused on the slit aperture of a 400.7 mm Rowland-circle spectrograph. The entire optical path of the telescope and spectrograph is evacuated prior to launch to prevent ion feedback in the spectrograph microchannel plate detector. In order to point the telescope, the visible light collected by the telescope is reflected from the mirrored surface of the slit jaw through a sealed quartz lens window into an on-board TV camera system, manufactured by Xybion Electronic Systems Corporation. This camera system is used to make real-time corrective maneuvers to the payload orientation via the Command Uplink System (CUS). The TV camera system consists of a model ISS-255 Video Camera retrofitted with modification CCU-01 for CCD readout inhibit, a model VIS-100 Integration and Storage module and an SE-580 dual-power supply module from Spacom Electronics, which supplies 12 volts to each of the other units. The video output is transmitted to the ground station and displayed on the CUS console.

The TV camera was turned on during flight at T+80 seconds. At approximately T+167 seconds into the flight, this video signal failed. The payload had not finished the pre-programmed maneuvers to the primary target star field at the time of failure. Upon finishing the pre-programmed maneuvers, without feedback via the TV image available, it was not possible to send the uplink commands necessary to place the stellar target in the spectrograph slit. This failure was mission-critical as it became impossible to achieve the minimum success criteria for the launch. All other systems, TM, ACS, S19, ORSA, Command Uplink System (CUS), experiment aperture doors, electronics, etc., performed nominally with the exception of the redundant data channel. Although no stellar spectra

were recorded, we note the vacuum modifications precipitated by flight 36.085 successfully prevented ion feedback in the spectrograph detector and 300 seconds of airglow spectra were recorded including emission from geocoronal Lyman-beta. Analysis of these data is currently being undertaken.

An analysis of the TV camera failure has been documented in the "36.109 UG Video Camera System Failure Investigation Final Report." This report describes how the problem with the Xybion TV camera system was traced to an overheated voltage regulator in the Spacom Electronics dual power supply (SE-580) that supplied 12 volts to the Xybion Integration Module. Specifically, the thermal epoxy bonding the voltage regulator to its heat sink developed a hairline crack large enough to thermally isolate the voltage regulator in vacuum causing it to overheat and fail. However, when operated in air the thermal contact was good enough to allow successful operation. When the flaw in the epoxy occurred is not known, though the supply worked nominally on the previous flight, 36.085UG, in December 1992. The power supply has been repaired, but we will probably replace it with a newer design for the reflight. As per the recommendations of the anomaly review committee we plan to implement vacuum testing of all experiment electronics, both pre-shake and post-shake, to prevent the recurrence of such failures.

The failure of the redundant serial data line was not mission critical as the pulse data was collected on TM1. This failure is still under investigation at JHU. It is currently believed to be a sensitivity on the part of the flight computer module to electrical transients in the experiment flight computer power bus. A workaround in the count-down procedure has been devised that will prevent recurrence of the transient and a possible reconfiguration of the experiment power control relays to remove the susceptibility to this problem is under study. This work is being done by Dr. Feldman, Dr. McCandliss and M. Martinez.

36.115 UG

We are completing the development of a new payload to image Jupiter in the band from 1200 Å to 1650 Å. The science goal is to obtain simultaneous images of the spectrally separated molecular and atomic hydrogen emission from Jupiter's aurora with 1 arc-second spatial resolution. To achieve the science objective, an aberration corrected dispersing prism, CCD detector, and image motion compensation servo are incorporated into a new sixteen inch f/24 Cassegrain telescope payload.

The telescope body and image motion compensation mechanism were designed and constructed by Research Support Instruments (RSI, Cockeysville, MD). The image motion compensation servo has been designed to compensate rocket jitter on the order of 0.25 arc-seconds at a frequency of about 100 Hz. This precision will be achieved with two Burleigh Inchworm piezoelectric motors that can tip and tilt the telescope secondary mirror to null an error signal produced by a quad-cell star tracker in the experiment. The image motion compensation mechanism passed a component-prototype level shake at Wallops in September, 1993.

The telescope mirrors were fabricated by D. Loomis of Tucson, AZ. The optics are nearly diffraction-limited, and a cell is being developed that will constrain the mirror safely during the rocket liftoff, yet still allow high resolution imaging. The spectrograph dispersing prism, made of LiF for high UV transmission, was manufactured by Janos Technologies (Townshend, VT). The prism has curved surfaces to correct the aberrations ordinarily incurred by a converging beam through a prism (P.F. Morrissey, "Third Order Aberrations of a Spherically Curved Prism Spectrometer", *Applied Optics* 33, 2539, 1994).

Several CCD detectors have been evaluated for sensitivity in the UV band of our experiment. We have examined front-side illuminated, phosphor-coated CCDs manufactured by Loral (Milpitas, CA) and provided by the Jet Propulsion Lab (P.F. Morrissey *et al.*, "Vacuum ultraviolet quantum efficiency of a phosphor-coated charge-coupled device," *Applied Optics* 33, 2534, 1994), and we have also calibrated a thinned, backside-illuminated device provided to us by Scientific Imaging Technologies (SITE, formerly Tektronix; P.F. Morrissey *et al.*, "Vacuum ultraviolet quantum efficiency of a thinned, backside-illuminated CCD," submitted to *Applied Optics*). We plan to use the thinned device in our payload because it has a larger active area and higher quantum efficiency than the Loral devices, which were developed for the CRAF and Cassini programs. A flight dewar with a Joule-Thomson cryostat that will cool the CCD to 160 K has been manufactured by R.G. Hansen and Associates (Santa Barbara, CA).

All of the electronics for the payload are being integrated and packaged by Spacom Electronics (Las Cruces, NM). We have received the detector flight electronics and expect delivery of the image motion compensation servo system this year. Once the electronics have been integrated into the experiment, we plan a thermal vacuum test of the payload at Wallops, and to focus the CCD camera at the Goddard UV collimator facility. Our current schedule calls for a focus test in early 1995 prior to integration at Wallops during late spring of 1995. This work is being carried out by P.F. Morrissey and Dr. McCandliss.

36.132 UG (& 36.136 UG)

This will be a reflight of 36.109 UG, from Australia, to obtain 3 long slit (100" x 12") far UV (FUV) spectra in the bandpass 912 - 1300 Å, with a resolution of ~10 Å, of the stars in and around R136, which is located in the 30 Dor region in the LMC, one of the largest giant H II regions in the local group of galaxies. The core of this nebula, R136, was once thought to be a supermassive star but has recently been shown by the newly refurbished HST to be composed of ~3000 hot stars. This cluster is now thought to have formed in a burst of star formation activity some 3.2 Myr ago. The proximity of such a large starburst region to our own galaxy provides a unique setting to view up close the structure of a starburst core and an opportunity to link its properties to starburst regions in more distant galaxies. The proposed observations will allow us to directly investigate the hottest stellar populations of the starburst region, the nebular extinction and provide a serendipitous search for nebular emission. The minimum on target time requested for completing this science program is more than can be accommodated in one flight of a Black Brant IX so a field refurbishment has been requested and given the flight number of 36.136 UG. This work is being carried out by J.B. McPhate and Dr. McCandliss.

Future Experiments

We are proceeding with the design of a high resolution FUV spectrograph that was initially described in our 1992 renewal proposal. This experiment will combine the normal incidence telescope with SiC reflective coatings developed for the G191-B2B calibration rocket (36.109UG and 36.085UG), and the FUV CCD flight hardware, developed for the Jupiter Auroral rocket (36.115UG), with a high ruling density, holographically ruled "FUSE-like" grating. This grating is an f/16 design and has a radius of curvature of 635.3 mm, an active area 44 mm in diameter, a ruling density of 5800 l/mm, and an ion-etched ruling profile to blaze the grating at 1026 Å. We expect to achieve a spectral resolving power of greater than 15000 when used with an open faced CCD with 12 micron pixels or smaller.

The spectrograph optical layout and grating parameters have been finalized. The spectrograph and CCD will be housed in a common evacuated housing, the design of which is in the process of being completed. A custom-built Joule-Thomson cryostat, mounted on a mini-conflat flange, for cooling the CCD with high pressure N₂ gas has been built by R.G. Hansen & Associates from a design provided by JHU. This miniature cryostat provides a great deal of temperature flexibility and eliminates the complications of flying a liquid nitrogen dewar. The grating, fabricated by the French company Jobin-Yvon through an agreement with our collaborator, Alfred Vidal-Madjar of the Institut d'Astrophysique de Paris (IAP), has been received. This grating has been supplied with a platinum coating, which will be sufficient for initial testing of the spectrograph, but for flight we will recoat it with ion-beam sputtered SiC at the GSFC Coates Laboratory for flight. We anticipate acquiring a large format, 9 micron pixel, CCD from our participation in a UV CCD development program headed by Jim Janesick at JPL sometime in late 1995. Two techniques, ion-implant with laser annealing, and molecular-beam epitaxy (MBE), are being investigated to achieve stable UV response on backside thinned CCD's. In the event that the 9 micron devices are unavailable we will use a lumigen coated 12 micron pixel device that was supplied to us by the CRAF/Cassini CCD development program.

Over the next few months we will conduct several laboratory studies of the high resolution spectrograph components. A means for cooling the open faced CCD without contaminating the chip and thereby degrading the UV sensitivity will be developed. We plan to carry out these tests with JPL supplied samples of CRAF/Cassini CCD's, which have a thinned region that has been treated by the MBE process. We will also assess the absolute efficiency, the scattering properties and the detector limited resolution of the grating. Finally, we will determine the quantum throughput of the assembled spectrograph. We expect the spectrograph to be ready for installation in the FOT following the Australia campaign so that the target date for launch from White Sands Missile Range is summer 1996.

Other Rocket Activities

During this period Dr. Feldman and Mr. Pelton supported the post-launch calibration efforts for the payload of Dr. John Clarke (University of Michigan), 36.101 UL, that was launched at White Sands Missile Range on June 15, 1993.

III. DETECTOR DEVELOPMENT

During the past few years we have shifted our emphasis in detector development from simplified readout schemes for microchannel plate (MCP) array detectors to the use of emerging large format CCD technology for ultraviolet applications. Such devices promise the ability to achieve higher resolution (either spectral or spatial) than is readily obtainable with MCP arrays, although their application is limited to experiments that do not require photon counting or solar-blind ultraviolet response. The work done to date by Mr. Morrissey is described above in the section on rocket 36.115UG and in the references cited therein. Recently, Dr. McCandliss has joined with J. Janesick of JPL in a successful proposal to the detector development program of the UV, Visible and Gravitational Astrophysics Branch to pursue the development and demonstration (in sounding rocket experiments) of CCD designs that will provide enhanced short wavelength sensitivity, higher spatial resolution and improved manufacturing yield with respect to existing visible and ultraviolet detectors. As a result of this program, we are baselining such a CCD for a 1996 experiment (see above) for high resolution FUV spectroscopy.

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